20,000 people obtained a living from this fishery. But since then, catches have fallen to around 5,000–10,000 tons but prices have risen substantially, maintaining the incentive to pursue this declining species.

Overfishing, in combination with habitat loss, pollution, the damming of rivers and climate change affecting ocean currents, have all contributed to the sharp decline in eel populations. The stock of juvenile eels is estimated to have declined by 95–99 per cent since 1980, Cites say. However, eels have a high survival rate, meaning that wild populations could recover if fewer young eels were caught.

The stock of juvenile eels is estimated to have declined by 95–99 per cent since 1980, Cites say. However, eels have a high survival rate, meaning that wild populations could recover if fewer young eels were caught.

The new Cites measures are now in place and it is hoped that they will help establish a sustainable fishery for the European eel. All exports now have to be accompanied by an export permit, which can only be issued after scientists in the exporting countries have confirmed that the levels of trade are not detrimental to the survival of the species and that the European eel is maintained, throughout its range, at a population level consistent with its role in the ecosystem, Cites say.

Exporting countries will need to re-evaluate their eel fishery management in order to meet these requirements. Importing countries will play their part by ensuring that all imported eels are accompanied by the required Cites export permits.

But, if there is any weakening in the ocean currents that bring the young eels across the Atlantic, no fishing controls are likely to have any impact on future populations.

Nigel Williams

Quick guides

Colony-level cognition

James A.R. Marshall[1] and Nigel R. Franks[2]

What is cognition? We favour the following definition of cognition: “cognition [is] the ability to use internal representations of information acquired in separate events, and to combine these to generate novel information and apply it in an adaptive manner” (Chittka and Osorio, 2007).

What is ‘colony-level cognition’? For some time now it has been recognised that colonies of certain social organisms, for example social insects such as ants or honeybees, can legitimately be regarded as functionally integrated ‘superorganisms’. In a social insect colony, colony-level cognition can be understood as cognition where internal representations are within the individual insects and their interactions with one another, just as in a brain the internal representations of cognition are in action potentials of neurons and their patterns of interaction.

Recently researchers working on collective decision-making by social insects have noted structural parallels between how house-hunting colonies are believed to reach decisions, and how neural circuits in the primate visual cortex achieve decision-making during motion-discrimination tasks (Figure 1). In both ant and honeybee colonies, and in the neural circuits, different populations act as integrators of noisy information on alternatives available in the environment, and a decision is reached when one of these integrator populations reaches a threshold. In both systems, these integrator populations may be arranged such that activation of one suppresses activation of the others. Finally, in both the social insect and neural systems, the decision threshold can be varied to achieve either quick but inaccurate, or accurate but slow decisions. Thus, these diverse cognitive systems, while appearing to be very different because of the differences in their physical implementations, actually seem to have very similar logical structures. This is just one example of what we call colony-level cognition.

Is colony-level cognition a new idea? The analogy between social insect colonies and brains is not new, originating most prominently with Douglas Hofstadter in his book ‘*Gödel, Escher, Bach*’. The phrase ‘collective intelligence’, championed by one of the authors (N.R.F.), has for two decades been applied to describe the behaviour of social insect colonies and other similar biological systems. Examples include foraging patterns of army ant raids, division of labour in honeybee colonies, and so on. In these systems, we suggest that the collective behaviour observed is indeed intelligent, in that it responds adaptively to the environment of the colony. But there is typically no obvious relationship between different collectively intelligent behaviours, other than a frequent reliance on the principles of self-organisation, or between these collective behaviours and behaviours that individual animals might exhibit. Thus, understanding these behaviours has to be undertaken on a case-by-case basis.

We propose, however, that colony-level cognition is distinct from collective intelligence, in that it rests on parallels between how social insect colonies function as cognitive systems, and how brains function as cognitive systems. We further propose that both individual and collective cognitive systems can benefit from this unified approach. We are not alone in arriving at this conclusion, as a recent review attests (see ‘*Where can I find out more?*’).

Why is colony-level cognition a useful idea? We believe a defining feature of the idea of colony-level cognition is that analysis and understanding of one system can provide insights for other systems. In other words, different cognitive systems, such as brains or social insect colonies, may be analysed and understood within the same framework because of their logical structure, regardless of the physical details of how this structure is implemented. Researchers have already taken the idea of analysing reaction-time distributions from

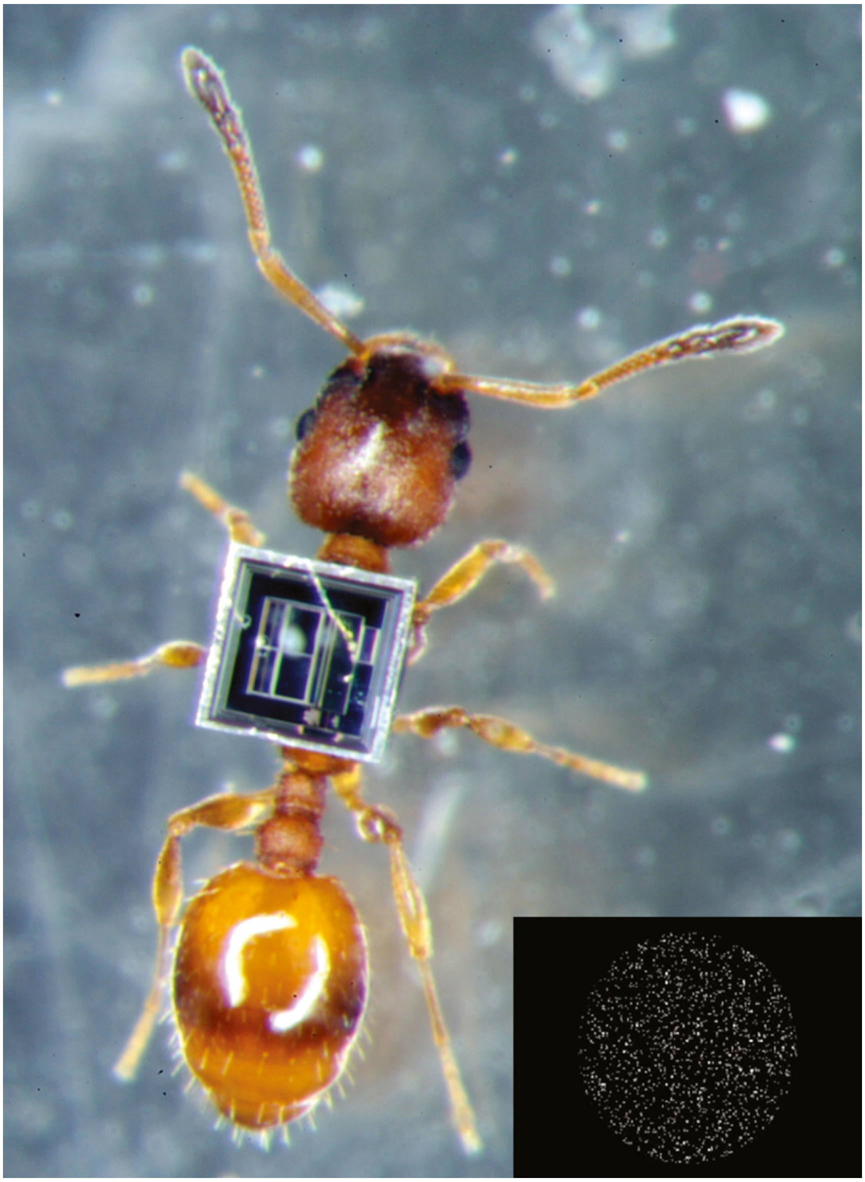

Figure 1. Collective decision making.

Social insects such as this *Temnothorax albipennis* ant (measuring 2 mm and marked with an RFID tag for identification) may solve collective decision-making problems using similar rules to those used by neural circuits in the primate visual cortex, which are able to solve motion-discrimination problems (inset). Both systems are able to vary the compromise between speed and accuracy of decision-making. Photo © Nigel R. Franks, random dot-field © Bill Newsome.

cognitive systems, which is well established in the study of neural cognitive systems, and applied it to the study of colony-level cognition in honeybees.

More recently we, together with colleagues, have taken mathematical models of decision-making in neural systems, which indicate how such systems should be configured to implement statistically optimal decision-making, and adapted their analytic techniques to study models of collective decision-making during emigration by ants and honeybees. This analysis produces an optimality hypothesis with testable predictions about how social insects should interact during emigration decisions; the first such hypothesis for this behaviour.

How far does the colony-level cognition metaphor stretch? The more one considers neural cognitive systems and colony-level cognitive systems, the more one realises the deep parallels between them, even when initially there are apparent differences. For example, it seems at first that social insect colonies are *different* to neural systems in that the former must actively sample uncertain information from their environment and then decide on it, while in neural models information on all alternatives is assumed to arrive at equal and unvarying rates. It quickly becomes clear, however, that in fact neural systems are also frequently faced with problems of this nature: this is the problem of active perception, where uncertain information can only be gathered from the environment by directing attention as appropriate. Thus, the study of how this is achieved during colony-level cognition may inform the study of how neural systems manage the same process, and vice-versa.

Another apparent difference is that in colonies of ants, for example, decision making and decision implementation appear to be conflated, whereas in brains they are apparently not. Yet understanding of the ants' problem can lead us to look at the neural system in a new light, and ask how a speed–accuracy trade-off in decision-making can be implemented such that consistent decision-implementation is realised. The question of how neural systems implement decision thresholds is indeed a current topic. Our basic message is that a unifying perspective can aid understanding of both individual-level and colony-level cognition.

Where can I find out more?

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